Verification of ensemble forecast using the physical parameterization schemes of WRF model during the Changma period over Korea.

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Background and Goals

• Recently, according to the increasing intensity and frequency of precipitation, weather disasters has been increasing. As a result, loss of lives and property has been increasing → The accurate precipitation forecast is very important.

• The accuracy of precipitation forecast has been improving with development of numerical model. But numerical model still has errors from uncertainty in the initial condition, the boundary condition and the inner model → The ensemble is very good skill to overcome the limitation of deterministic forecast.

• In this study, we made an effort to compose the Ensemble Prediction System (EPS) with 120 ensemble members by using the combinations of different physical parameterization schemes, and we found the combination of best physical parameterization schemes and estimated ability of ensemble prediction system.

Ensemble forecast experiment design

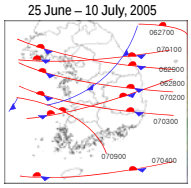
WRF model experiment design

• Physics scheme : 120
(8 microphysics × 5 cumulus × 3 PBL)
• Model runs : 7680, 4 run /day (00, 06, 12, 18UTC)
(120 member × 16 days × 4 run /day = 7,680)
• Evaluation cases per physics scheme: 64
(7680 runs / 120 member = 64 runs / member)
• Forecast time : 36-hr forecast at 1-hr intervals

Case

• The Changma front over the Korean Peninsula

25 June – 10 July, 2005



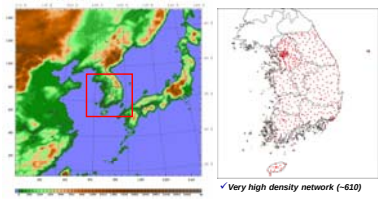
Verification

• 6-hr accumulated precipitation
• 610 Automatic Weather Station (AWS) rain gauge data over Korea

Configurations of WRF v2.2.1

Horizontal grid spacing	18 km (148 × 148)
Vertical layer	35 sigma layers
Model top	50 hPa
Radiation	SW : Dudhia, LW : RRTM
Soil temperature	LW 5-layer Soil Model
Initial, lateral boundary condition	NCEP FNL

Domain



✓Very high density network (~610)

Ensemble Member (WRF v2.2.1)

Member	Microphysics	Cumulus	PBL
M01 – M08	KES - NC5	NOC	MRF
M09 – M16	KES - NC5	KF1	
M17 – M24	KES - NC5	KF2	
M25 – M32	KES - NC5	BMJ	
M33 – M40	KES - NC5	GDE	
M41 – M48	KES - NC5	NOC	YSU
M49 – M56	KES - NC5	KF1	
M57 – M64	KES - NC5	KF2	
M65– M72	KES - NC5	BMJ	
M73 – M80	KES - NC5	GDE	
M81 – M88	KES - NC5	NOC	MYJ
M89 – M96	KES - NC5	KF1	
M97 – M104	KES - NC5	KF2	
M105 – M112	KES - NC5	BMJ	
M113 – M120	KES - NC5	GDE	

microphysics

1. KES : Kessler
2. WSM3 : WSM 3-class simple ice
3. WSM5 : WSM 5-class
4. FER : Ferrier (new Eta)
5. WSM6 : WSM 6-class graupel
6. THO : Thompson *et. al* graupel
7. NC3 : NCEP 3-class simple ice
8. NC5 : NCEP 5-class

Cumulus

1. NOC : No convection
2. KF1 : Kain-Fritsch I
3. KF2 : Kain-Fritsch II
4. BMJ : Betts-Miller-Janjic
5. GDE : Grell-Devenyi ensemble

PBL

1. MRF : Medium-Range Forecast
2. YSU : Yonsei University
3. MYJ : Mellor-Yamada-Janjic

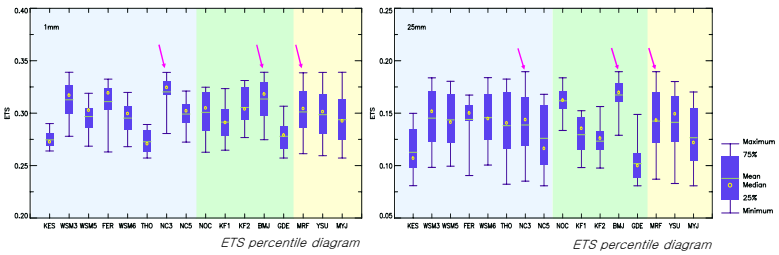
Sensitivity

Sensitivity of WRF physics: light rain

• best combination : NCEP 3class – BMJ - MRF
• light rain (> 1 mm / 6hr) : microphysics > cumulus

Sensitivity of WRF physics: moderate rain

• best combination : NCEP 3class – BMJ - MRF
• moderate rain (> 25 mm / 6hr) : cumulus > microphysics



ETS percentile diagram　　ETS percentile diagram

Odds & Odds Ratio

Odds

$$\text{Odds} = \frac{P}{(1-P)}$$

• The odds of an event is the ratio of the probability that the event occurs to the probability that the event does not occur
• Ranges : 0 ~ infinity, P: probability

Odds Ratio

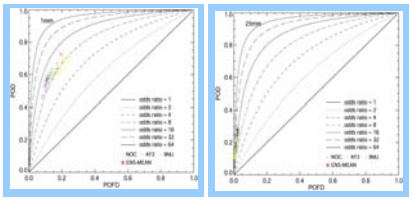
* Contingency table

Event forecast	Event observed	
	Yes	No
Yes	Hit (a)	False alarm (b)
No	Miss (c)	Rejection (d)

	Hit rate (POD)	False alarm rate (POFD)
Odds	POD/(1-POD)	POFD/(1-POFD)
	a/(a+c)	b/(b+d)
forecast	good	bad

$$\theta = \frac{\text{POD}}{1-\text{POD}}\left(\frac{\text{POFD}}{1-\text{POFD}}\right)^{-1} = \frac{ad}{bc}$$

• By using the odds ratio, forecast skill can be judged by comparing the odds of making a good forecast (a hit) to the odds of making a bad forecast (a false alarm)
• Ranges : 0 ~ infinity, 0 ~ 1 indicates no skill, perfect score : infinity
• Note that the odds ratio is not the same as the ratio of the probability of making a hit (hits / # forecasts) to the probability of making a false alarm (false alarms / # forecasts), since both of those can depend on the climatological frequency (i.e., the prior probability) of the event

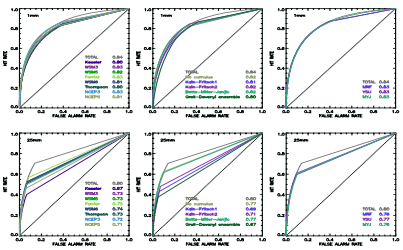


• BMJ, KF2 and NOC scheme combinations were sensitive (> 25mm/6hr) → Comparison with BMJ, KF2 and NOC scheme combinations by using odds ratio

	1mm/6hr	25mm/6hr
NOC	8.14 ~ 11.70	10.65 ~ 17.35
KF2	7.28 ~ 11.14	10.50 ~ 18.02
BMJ	8.53 ~ 12.25	11.68 ~ 21.34
ENS-MEAN	10.99	26.83

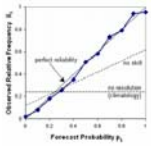
• Overall, ensemble members of BMJ scheme combination showed a tendency to have high odds ratio score in comparison with the others
• Most of the thresholds, NC3-BMJ-MRF (M31) showed high odds ratio score → Similar to the result of sensitivity
• Ensemble mean showed the highest odds ratio score above 10mm/6hr

ROC curves of WRF physics ensemble forecast



• Ensemble forecast by using 120 members showed the largest ROC area.
• ROC area of light rain (> 1mm/6hr)
: microphysics >cumulus
• ROC area of moderate rain (>25mm/6hr)
: cumulus > microphysics
• Using BMJ and NOC scheme has more benefit for the ensemble probability forecast
• It is very important to select the cumulus parameterization scheme in physics ensemble

Reliability diagram



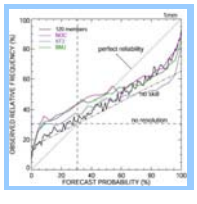
Reliability

• The reliability measures the ability of the system to forecast accurate probabilities
• Agreement between forecast probability and mean observed frequency → $p_k = \bar{o}_k$: perfect forecast (diagonal line)
• If the curve lies below the diagonal line → overestimation
• " above the diagonal line → underestimation

Resolution

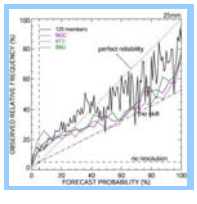
• The ability of the forecast system to correctly separate the different categories, whatever the forecast probability → The ability of the forecasts distinguish between events and non-events
• Max. resol. : deterministic forecast (0% and 100% forecast probability)
• Min. resol. : climatological forecast

1mm/6hr



• Ensemble forecast of NOC and BMJ scheme combination showed an underestimation below 50% and an overestimation above that. Ensemble forecast of KF2 scheme combination showed an underestimation below 40% and an overestimation above that, and no skill from 70 % to 95%. KF2 showed better reliability than the others in low probability forecast, NOC in high one
• Ensemble forecast by using 120 members showed a good reliability below 45%, more poor reliability than NOC and BMJ from 45% to 70%. similar pattern to NOC and BMJ above 70%

25 mm/6hr



• According to the increasing of threshold, KF2 showed a similar tendency to NOC and BMJ
• Overall, the reliability was more poor than one of low thresholds. All of the thresholds, ensemble probability forecast by using 120 member showed a tendency of the best reliability

Summary and Conclusions

▪ In this study, we composed the Ensemble Prediction System (EPS) with 120 ensemble members by using the combinations of different physical parameterization schemes. We conducted the numerical simulation with this EPS during the Changma period (from 25 June to 10 July 2006), four times a day ie, 00, 06, 12, 18UTC for each day. The simulated 6-h accumulated precipitation amounts were verified against with 610 Automatic Weather Station (AWS) rain gauge data over Korea.

▪ In terms of the equitable threat score (ETS), we found that the combination of NCEP 3 class microphysics, BMJ cumulus parameterization and MRF PBL scheme revealed the best forecast skill for both light rainfall event (>1mm/6hr) and moderate rainfall event (>25mm/6hr) have. The EPS using the ensembles of microphysics showed more sensitivity for light rainfall events, while the experiment using the ensembles of cumulus parameterization scheme showed more sensitivity for moderate rainfall events.

▪ Ensemble forecast of BMJ scheme combination showed high odd ratio in comparison with the other members, and Ensemble mean showed the highest score above 10mm/6hr.

▪ Ensemble forecast by using 120 members showed the largest ROC area in all thresholds and ensemble forecast of cumulus parameterization scheme combination showed larger ROC areas than the others above 25mm/6hr.

▪ Overall, ensemble forecast of NOC and BMJ scheme combination showed a similar pattern in reliability for the range of high probability forecast and the ensemble forecast of KF2 scheme combination showed low reliability. All of the thresholds, ensemble probability forecast by using 120 member showed a tendency of the best reliability.